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Forest Habitat Associations of the Golden-mantled Ground Squirrel: Implications for Fuels Management

Abstract

Golden-mantled ground squirrels are commonly associated with high-elevation habitats near or above upper timberline. This species also occurs in fire-adapted, low-elevation forests that are targeted for forest health restoration (FHR) treatments intended to remove encroaching understory trees and thin overstory trees. Hence, the golden-mantled ground squirrel may be affected by FHR treatments, but little is known about its habitat associations within these forest types. We sampled mature western larch and ponderosa pine forests in western Montana to determine the macro- and microhabitat associations of this ground squirrel. At the macrohabitat scale, golden-mantled ground squirrels were absent from western larch stands which consistently had a denser understory. Because we did not detect golden-mantled ground squirrels within larch stands, it is unclear whether FHR treatments in this forest type would improve habitat conditions for these ground squirrels. In contrast, golden-mantled ground squirrels were common in ponderosa pine stands and favored more open conditions there. At the microhabitat scale within ponderosa pine stands, golden-mantled ground squirrels were captured at trap stations with fewer canopy trees, more rock cover, and less grass and forb cover compared to stations without captures. Thus, FHR treatments that open the understory of ponderosa pine stands while maintaining mature pines similar to historic conditions may increase golden-mantled ground squirrel populations. However, the extent to which golden-mantled ground squirrels are positively affected by FHR treatments in ponderosa pine stand types may be limited by the degree of their dependence on rocky structure.

Introduction

Recent severe wildfires in the western United States have prompted changes in forest management practices with important implications for wildlife. Studies suggest that fire suppression has lead to increased fuel loading that has elevated the risk and severity of wildfires occurring in certain lower elevation forest types (Schoennagal et al. 2004). As a result, forest management on public lands is increasingly focused on reducing fuel loads in the affected habitats through programs such as the National Fire Plan (http://www.fireplan.gov) implemented under the Healthy Forests Restoration Act of 2003 (Schoennagal et al. 2004). In western Montana, seral ponderosa pine (*Pinus ponderosa*) and western larch (*Larix occidentalis*) are the forest types considered to be most affected by past fire suppression, because seral ponderosa pine and western larch historically persisted as dominant overstory types only in the presence of frequent, low-intensity fires that suppressed shade tolerate late successional species (Arno et al. 1997). Thus, forest health restoration (FHR) strategies in this area currently employ mechanical and burning treatments to reduce understory trees and thin overstory trees, particularly in seral ponderosa pine and western larch types. Presumably, wildlife species that favor forest conditions with higher densities of understory and overstory trees will decline in response to FHR treatments, while species adapted to more open conditions associated with lower densities of understory and overstory trees will increase. To the extent that such treatments restore historic vegetation conditions, we should also expect them to restore historic wildlife conditions. However, little work has been done to examine this question.

The golden-mantled ground squirrel (*Spermophilus lateralis*) is a widely distributed rodent within the mountainous regions of the western United States and Canada (Bartels and Thompson 1993), where it plays numerous important

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ecological roles. This ground squirrel is prey for forest carnivores like the American marten (*Martes americana*), and raptors like the northern goshawk, (*Accipiter gentilis*), which are species of concern over much of their range (Reynolds and Meslow 1984, Reynolds et al. 1992, Waters and Zabel 1998, Squires 2000). The burrows of golden-mantled ground (GMG) squirrels are used by hibernating boreal toads (*Bufo boreas*), a species that has declined over much of its range (Wind and Dupuis 2002). GMG squirrels consume a wide variety of forbs and herbs, conifer seeds, grasses, and fungi (McKeever 1964, Goodwin and Hungerford 1979, Bartels and Thompson 1993), which can potentially affect local plant community dynamics. For example, as an important predator of conifer seeds and young seedlings (McKeever 1964), GMG squirrels may have contributed to maintaining the open conditions of historic ponderosa pine stands. GMG squirrels also prey on insects, small mammals, nesting birds, eggs, lizards and carrion (McKeever 1964, Goodwin and Hungerford 1979, Bartels and Thompson 1993, Foresman 2001). Thus, management activities that alter conditions for GMG squirrels may affect numerous other organisms through food-web interactions, although the strength of these interactions is not well understood.

The GMG squirrel commonly inhabits rocky areas above timberline (Foresman 2001), where it is unlikely to be affected by forest management practices. However, these squirrels also inhabit a number of forest types, appearing to be the most abundant in open, pure stands of ponderosa and other pines (Bartels and Thompson 1993). They also occur to a lesser extent in lodgepole pine (*Pinus contorta*), mixed fir forests (McKeever 1964), dry mixed conifer sites (Hayward and Hayward 1995), rocky slopes adjoining grasslands, areas of scattered chapparal, margins of mountain meadows (Bartels and Thompson 1993), and sagebrush and juniper habitats (Fitzgerald et al. 1994). The GMG squirrel avoids dense stands (McKeever 1964), but will disperse through them to reach clearings and will invade dense areas if they are logged (Tevis 1956). Although they have been detected in a variety of habitat types, macro- and micro-habitat associations in lower elevation forests such as ponderosa pine and western larch are poorly known. The objective of this study was to determine the macro- and microhabitat associations of GMG squirrels in ponderosa pine and western larch forests in western Montana, and to evaluate whether new forest management practices might impact squirrel populations through the alteration of preferred habitat elements.

Study Area

We sampled populations of GMG squirrels in nine mature ponderosa pine and western larch stands in western Montana. Sites were located on the Bitterroot and Lolo National Forests and spread over a large area approximately 47 by 73 km, representing four drainages within the Bitterroot Valley south of Missoula, two drainages in the Rock Creek Valley southeast of Missoula, two drainages in the Fish Creek area west of Missoula, and one drainage at Plant Creek near Missoula (mean distance between sites was 41.7 km, SD = 21.2 km). Five study sites were dominated by an overstory of ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*) (referred to as Ponderosa pine-Douglas-fir sites). Common understory species included snowberry (*Symphoricarpos albus*), serviceberry (*Amelanchier alnifolia*), ninebark (*Physocarpus monogynus*), kinnickinnick (*Arctostaphylos uva-ursi*), bluebunch wheatgrass (*Pseudoroegneria spicatum*), and *Arnica* species. The Ponderosa pine-Douglas-fir study sites were located on south to southeast aspects and ranged from 1200-1800 m elevation. None of the sites had been previously logged, but two sites, Hogback Ridge and Lupine Creek, both experienced low-severity understory burns within approximately 10 yrs before the sampling period. The other four study sites (referred to as Larch-Fir sites) contained various densities of western larch, subalpine fir (*Abies lasiocarpa*), Douglas-fir, lodgepole pine, Engelmann spruce (*Picea engelmannii*), grand fir (*Abies grandis*), and ponderosa pine. Common understory species included ninebark, serviceberry, and pine grass (*Calamagrostis rubescens*). The Larch-Fir study sites were located on north aspects and ranged from 1200-1800 m elevation.

Methods

At each site, three trapping grids and three trapping transects were established to survey GMG squirrels. Both grids and transects consisted of 25 Sherman traps spaced 10 m apart, for a transect length of 240 m and a grid area of approximately 0.25 ha. Starting points for grids and transects were randomly assigned by placing a grid (interval ca. 0.75 km) over a quad map of the study area and randomly choosing grid intersection points. Transects were added to supplement grids for capturing rare species for better resolution of small mammal community composition (Pearson and Ruggiero 2003). Since traps are merely sampling animal distribution, there is no reason to believe that trapping arrangement alters habitat use by GMG squirrels. Moreover, the analytical method used is robust to the addition or deletion of variables that might result from transects picking up additional microsites not sampled by grids (Manly et al. 1993). When we analyzed grids and transects separately, results were comparable to when we analyzed grids and transects together, so both data sets were pooled. Trapping sessions occurred in May and June for 8 consecutive days at each site once per year for a total of approximately 1200 trap nights per year per site. During each trapping session, folding Sherman live traps were placed at each trap site and baited with a mixture of rolled oats and peanut butter. Traps were left open overnight and checked from 0700 to 1100 hrs. Captured animals were tagged with #1005-1 monel ear tags (National Band and Tag Company, Newport, Kentucky 41072-0430), and were released at the point of capture.

At each trapping site, we assessed vegetation within a 5 m radius of the trap (after Pearson et al. 2000, 2001). Percent cover was estimated to the nearest five percent for rock surface, grass and forbs, ground-hugging shrubs (e.g., kinnikinnick), low shrubs (< 1 m tall and not ground-hugging), high shrubs (> 1 m tall), saplings (conifers > 1 m tall and < 5 cm dbh), young trees (conifers > 1 m tall and 5-8 cm dbh), litter (1997 only), moss, soil, and surface water. All deciduous trees < 5 cm dbh were treated as shrubs, and cover was estimated for the appropriate height class. All conifers > 5 cm dbh were treated as trees and measured individually. Each was labeled as a live tree, snag, log, rootwad, or stump. For live trees and snags, dbh was measured in 10 cm increments. For logs, diameter measurement was taken parallel to the ground. The total number of canopy trees, snags, and logs was averaged per plot. Canopy tree diameter classes were also grouped in the following manner: trees < 10 cm dbh, trees 10-30 cm dbh, and trees > 30 cm dbh. Coarse woody debris was defined as down logs in the following categories: logs < 10 cm diameter, logs > 10 and ≤ 30 cm diameter, and logs > 30 cm diameter. All other vegetative variables remained as percent cover values. The vegetative characteristics of the two stand types were contrasted using a single factor analysis of variance (ANOVA) (SPSS Incorporated 1999). For the microhabitat analysis, values of vegetative characters were considered at the plot-level (5 m radius circle) within each stand.

The number of GMG squirrel individuals present during a trapping period was used as an index of their abundance for site-level macrohabitat analysis (McKelvey and Pearson 2001). Data were pooled between years because there were not sufficient data for robust analyses for separate years. Individuals were only counted once if they were captured in both years. To determine microhabitat selection, trap stations were identified as capture or non-capture sites for individual GMG squirrels. Stations were only counted once, whether they received one or multiple captures. We evaluated habitat use by GMG squirrels using logistic regression in the context of Resource Selection Function Analyses (Manly et al. 1993). We used stepwise logistic regression based on likelihood ratio tests (SPSS Incorporated 1999) to determine which habitat variables best differentiated trap stations that captured GMG squirrels from those that did not. Both forward and backward stepwise entry approaches generated the same final models. Prior to analyses, we screened for variables with high correlations (Tabachnick and Fidell 1989). Level of significance was set at $P = 0.05$.

Results

We captured a total of 61 individual GMG squirrels in the 1996 and 1997 trapping seasons. The majority of animals (87%) were adults, because trapping was early relative to emergence of young (Foresman 2001). GMG squirrels were caught at the following sites: 30 individuals at Big Creek, 15 individuals at Brewster Creek, 7 individuals at Hogback Ridge, 5 individuals at Lupine Creek, and 4 individuals at Burdette Creek. GMG squirrels were not captured on any Larch-Fir site, but were captured at all Ponderosa pine-Douglas-fir sites in both years. Ponderosa pine-Douglas-fir sites differed structurally from Larch-Fir sites in that they had lower sapling cover ($t = 2.9$, $df = 7$, $P = 0.02$), higher rock cover ($t = -2.7$, $df = 4.3$, $P = 0.05$), and less small tree cover ($t = 3.3$, $df = 7$, $P = 0.01$) (Table 1). Ponderosa pine-Douglas-fir sites also had fewer canopy trees per vegetation

TABLE 1. Mean values (± SE) of major structural features of five Ponderosa pine-Douglas fir and four Larch-fir stands sampled in western Montana. Significant differences (*P* value of t-test) between the two sites are indicated (NS denotes no significant difference).

Structural feature	Larch-Fir	Ponderosa pine-Douglas-fir	*P*-value
Rock cover (%)	1.69 ± 0.81	12.95 ± 4.14	0.05
Grass/forb cover (%)	36.07 ± 4.28	31.70 ± 5.68	NS
Ground-hugging shrub cover (%)	4.09 ± 1.99	4.50 ± 1.73	NS
Low shrub cover (%)	19.77 ± 5.97	9.96 ± 2.82	NS
High shrub cover (%)	21.34 ± 9.68	6.68 ± 1.97	NS
Litter cover (%)	60.13 ± 7.64	38.02 ± 10.06	NS
Moss cover (%)	6.66 ± 3.53	2.04 ± 0.53	NS
Bare soil cover (%)	2.32 ± 0.53	5.76 ± 1.74	NS
Sapling cover (%)	2.45 ± 0.49	0.93 ± 0.27	0.02
Small tree cover (%)	8.89 ± 1.23	3.59 ± 1.06	0.01
Snag density (#/ha)	158.22 ± 40.00	103.21 ± 11.17	NS
Tree density 0-10 cm dbh (#/ha)	410.46 ± 155.13	89.09 ± 34.85	<0.001
Tree density 10-30 cm dbh (#/ha)	452.18 ± 180.7	131.45 ± 30.24	<0.001
Tree density > 30 cm dbh (#/ha)	131.90 ± 18.76	81.64 ± 7.22	<0.001
Log density < 10 cm diameter (#/ha)	1202.50 ± 480.26	247.24 ± 60.71	NS
Log density > 30 cm diameter (#/ha)	367.78 ± 153.64	60.08 ± 12.00	NS

TABLE 2. Summary of logistic regression model predicting golden-mantled ground squirrel capture sites from five ponderosa pine-Douglas-fir stands in western Montana.

Variable	Coefficient	SE	*P*-value
Rock cover (%)	0.02	0.01	<0.001
Grass and forb cover (%)	-0.02	0.01	<0.001
Canopy trees > 10 cm dbh (#/ha)	-0.44	0.11	<0.001

plot in all size classes: < 10 cm dbh (t= 16.6, df = 1484.6, $P < 0.001$), 10-30 cm dbh (t= 19.4, df = 1639.4, $P < 0.001$), and > 30 cm dbh (t= 8.5, df = 2297.2, $P < 0.001$) (Table 1).

Three microhabitat variables were selected for inclusion in a logistic regression model differentiating between trap stations with squirrel captures and those without captures in Ponderosa pine-Douglas-fir sites (model $\chi^2 = 81.25$, $P < 0.001$): number of canopy trees > 10 cm dbh, percent cover of rock, and percent cover of grass and forbs (Table 2). There were less than half as many canopy trees > 10 cm dbh at capture stations than non-capture stations (Table 3). Percent cover of rock was over twice as high at capture stations than non-capture stations and percent cover of grass and forbs was lower at capture stations (Table 3).

TABLE 3. Mean values (± SE) of significant structural variables for stations that captured or did not capture golden-mantled ground squirrels in five ponderosa pine-Douglas-fir stands in western Montana. Rock and grass and forb cover were measured as percent cover values, while canopy trees > 10 cm dbh were measured in terms of density per hectare.

Variable	Captures	No Captures
Rock cover (%)	25.37 ± 1.96	11.37 ± 0.44
Grass and forb cover (%)	22.64 ± 1.72	33.12 ± 0.7
Canopy trees > 10 cm dbh (#/ha)	82.32 ± 17.59	203.62 ± 6.52

Discussion

At the macrohabitat level, we detected GMG squirrels in the mature Ponderosa pine-Douglas-fir stand type, but not in the more mesic Larch-Fir stand type, which had a denser overstory and understory. The stand characteristics of the Ponderosa pine-Douglas-fir stand type fit within the open forest or rocky macrohabitat found to be preferred in other studies (McKeever 1964, Bartels and Thompson 1993, Hayward and Hayward 1995). We found a number of microhabitat elements to be related to GMG squirrel captures in this study. The strongest association was a negative relationship with canopy tree density, which supports the well-documented preference of GMG squirrels for mature, open stands (McKeever 1964, Reynolds et al. 1992, Woolf 2003). Goodwin and Hungerford (1979) found GMG squirrels in both open and dense pine stands. Tevis (1956) found GMG squirrels moving into previously unoccupied dense stands that had been opened by logging. GMG squirrel populations also significantly increased in old growth white fir (*Abies concolor*) and red fir (*A. magnifica*) forests that underwent shelterwood logging (Waters and Zabel 1998). Open stands allow for the development of a vigorous shrub and herbaceous layer, both of which provide important dietary components (McKeever 1964, Reynolds et al. 1992).

We also found a positive association between GMG squirrel captures and percent groundcover of rock, an affinity that is well supported in the general literature (Reynolds et al. 1992, Bartels and Thompson 1993, Bihr and Smith 1998, Foresman 2001). Rocky areas provide sites for nesting and hibernating, protection from predators, and offer basking and lookout locations (Bihr and Smith 1998).

We found a negative association between capture success and grass and forb cover, which has not been reported in previous studies. While grasses have been found to comprise a small portion of the diet (Goodwin and Hungerford 1979), forbs are listed in all studies as being seasonally important dietary components (McKeever 1964, Goodwin and Hungerford 1979). It is quite possible that the GMG squirrel, which is a central-place forager, reduces grass and forb cover at the microhabitat level through concentrated feeding, and what we actually measured here was not selection for low levels of grass and forb, but rather foraging impact on these elements. The ability of a small mammal to reduce the local abundance of grass and forb cover has been documented with the pika (*Ochotona princeps*), and it has been suggested that other central-place foragers would likewise impact local vegetation (Huntly 1987).

The combination of logging and absence of fire for 70 to 90 years has resulted in the widespread proliferation of Douglas-fir on sites that were formerly maintained in ponderosa pine (Gruell 1983). On the Bitterroot and Lolo National Forests of westcentral Montana, surface fuels and conifer thickets have developed in the absence of underburns for 60-90 years (Arno et al. 1995). Sites have also exhibited an increase in basal area and in number of trees per acre and developed an understory of shade-tolerant trees, the majority of which are Douglas-fir (Arno et al. 1995). Restoration treatments for these areas include decreasing both understory and overstory tree density. We did not detect any GMG squirrels in the Larch-Fir sites with dense overstory and understory cover, but it is unclear whether this is due to the vegetation conditions, the cooler wetter north aspects, or a combination of these factors. Within the Ponderosa pine-Douglas-fir sites where we did detect GMG squirrels, increasing overstory and understory cover was associated with increasing presence of Douglas-fir and a decreasing relative abundance of GMG squirrels. The opening of these stands might favor GMG squirrels, as was seen elsewhere in Montana (Woolf 2003), though we did not experimentally test this hypothesis.

The habitat elements found to be important in this study have the potential to be altered with active forest management. Rock cover is not likely to change in stands that undergo fuels management or restoration activities such as prescribed burning and thinning. However, the two remaining habitat elements both stand to change with such practices. Though it is not clear how changes in grass and forb cover would impact GMG squirrels, a reduction in the density of canopy trees may potentially make an area more suitable as GMG squirrel habitat. Indeed, such a pattern was seen in manipulated ponderosa pine stands in western Montana (Woolf 2003) and Arizona (Medin 1986), as well as Douglas-fir, white fir and red fir stands in California (Tevis 1956, Waters and Zabel 1998). However, it is interesting to note that the two stands in this study that underwent low-severity understory burns within the past 10 years had among the lowest number of GMG squirrels captures. While this result may be attributed to the lack of rock cover in these sites, additional work into how long treated stands maintain the habitat conditions preferred by GMG squirrels is warranted. We suggest that experimental research is necessary to better understand the effects of new forest management practices on this species.

While we believe that management actions to restore ponderosa pine forests to more open historical conditions could result in an increase in populations of GMG squirrels, we also recognize that restoration treatments may alter other vegetative dynamics that may not be favorable to GMG squirrels. For example, FHR treatments could increase exotic invasive plants in the understory, since most exotic plants respond positively to disturbance (e.g., Davis et al. 2000). The response of GMG squirrels to the nature and extent of exotic plant invasions resulting from restoration treatments will determine whether the potential positive effects of restoration of overstory conditions in ponderosa pine forest types actually favors GMG squirrels.

Management of forests for fuels reductions and restoration to historic conditions is of primary concern in the intermountain west. The impacts of such treatments on wildlife species are poorly understood. We identified habitat associations of GMG squirrels in two forest types of western Montana that are targeted for FHR treatments. We found that GMG squirrels inhabited all five of the sampled lower elevation Ponderosa pine-Douglas-fir forest stands but were absent from Larch-Fir stands. Furthermore, we found that within the Ponderosa pine-Douglas-fir forest type, the GMG squirrel was associated with stand structural variables that may be affected by FHR treatments. Because GMG squirrels are an important component of the forest ecosystem in the intermountain west, it is important to understand how FHR treatments may impact GMG squirrel populations.

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